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(54) Fibre from tube

(57) A process for fabricating an optical fibre, in which a lining 30 of synthetic glass is formed inside a quartz tube 31, which is then collapsed while being drawn in a drawing furnace 33: the ratio of the inner diameter/outer diameter of the quartz tube is 0.85 or less, and the internal pressure of the quartz tube is maintained under negative pressure. The process prevents the invasion of moisture from the exterior and the drawing and collapsing steps occur reliably and stably.

F I G. 1

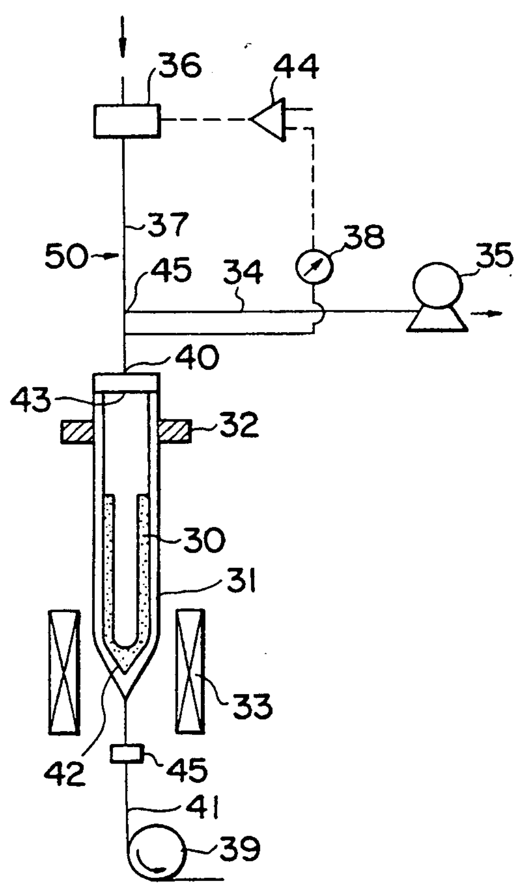

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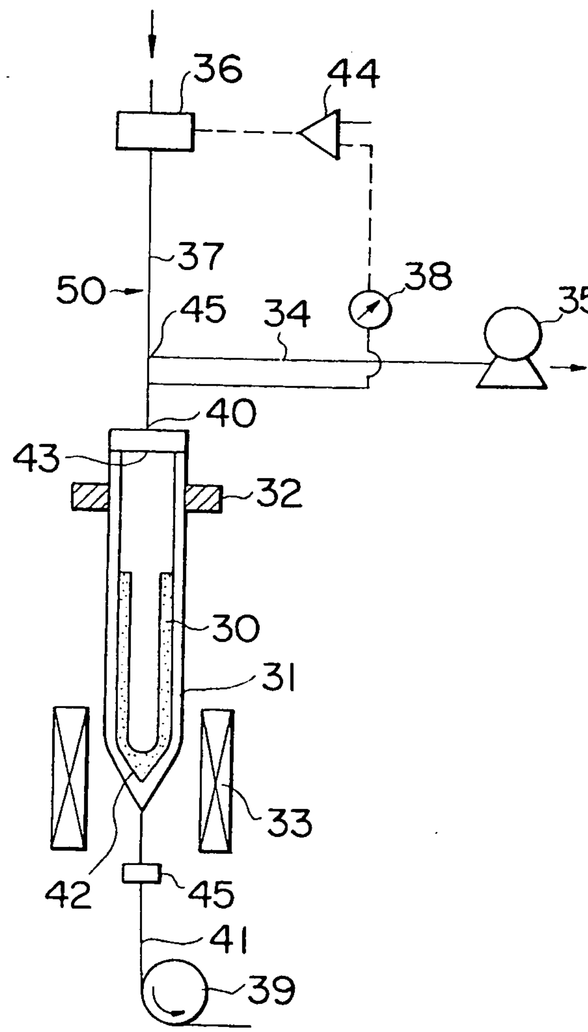
FIG. 1



F I G. 2

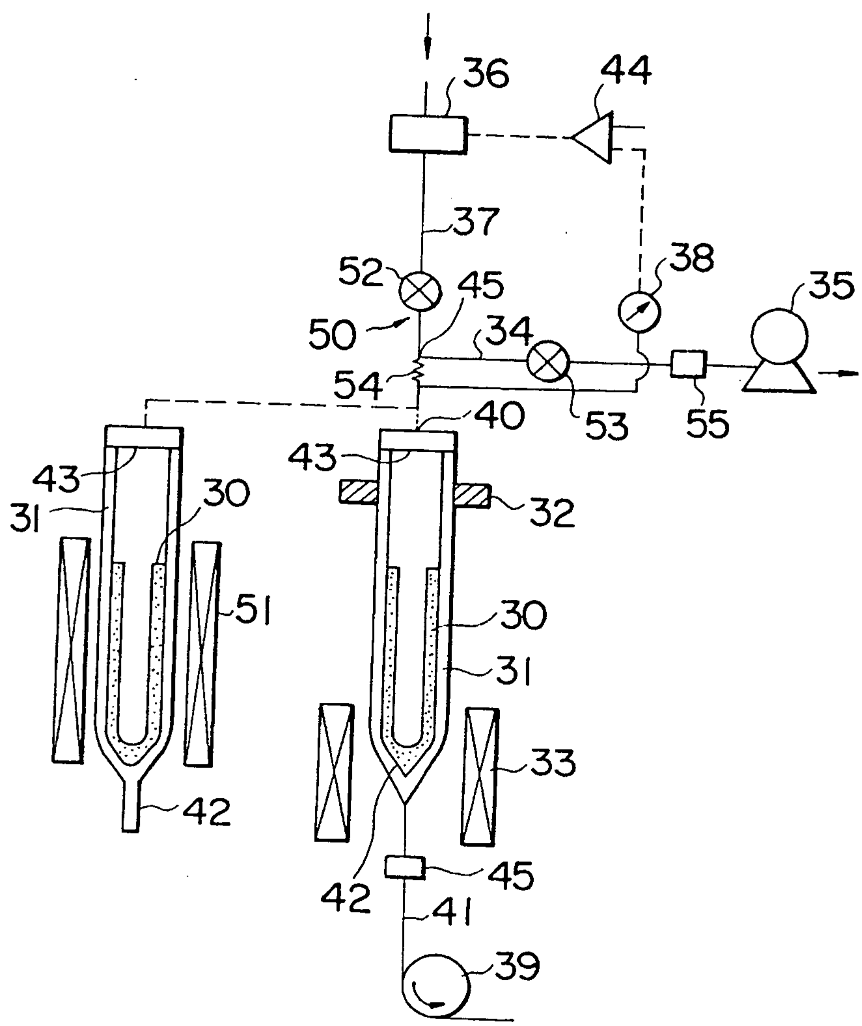

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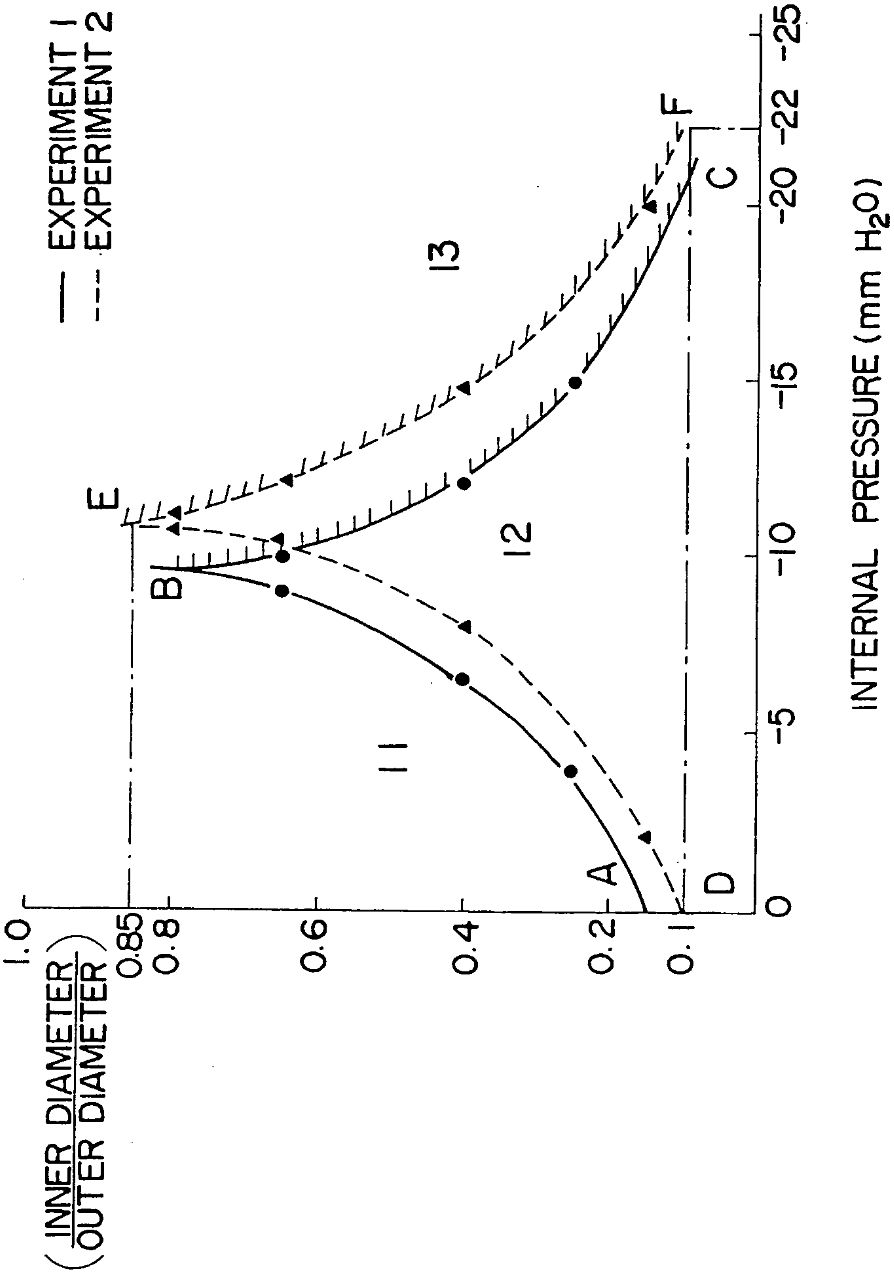
FIG. 3


EXPERIMENT 1
EXPERIMENT 2
(INNER DIAMETER / OUTER DIAMETER)
1.0
0.85
0.8
0.6
0.4
0.2
0.1
0
-5
-10
-15
-20
-22
-25
INTERNAL PRESSURE (mm H_2O)
A
B
C
D
E
F
11
12
13

SPECIFICATION

Process for fabricating optical fibre

This invention relates to a process for producing an optical fibre by a modified CVD method (MCVD) method).

A process for producing an optical fibre is known which has the steps of forming a lining of a synthetic glass on the inside of a quartz tube (the synthetic glass having a refractive index higher than the quartz) to form a core, then wire-drawing this in a wire-drawing furnace and simultaneously collapsing it. For example, this process is disclosed in U.S. Patent No. 3,711,262. The process comprises the steps of heating the quartz tube to a high temperature at the drawing time to soften it and cause it to contract by its surface tension, thereby providing an advantage that the production efficiency is high owing to the simultaneous steps of drawing and collapsing.

However, in this conventional process, the heating conditions required for collapsing the tube and the heating conditions necessary for drawing do not always coincide. As a result, there arise various drawbacks that the central portion of the optical fibre is not solidified (a so-called "incomplete collapsing") or its circularity in the case of solidifying is deteriorated to cause it to be deformed so that the collapsing step becomes unstable. Further, when heating conditions for collapsing are preferentially prepared, another drawback arises that the drawing conditions are restricted.

In addition, the tube made by forming a core in the quartz tube, as described above, is hollow in the center, and moisture in the atmosphere is mixed in during the drawing step, such that moisture is introduced into the optical fibre at the time of drawing to cause an increase in the transmission loss of the optical fibre.

Accordingly, an object of this invention is to provide a process for fabricating an optical fibre involving sumultaneously wire-drawing and collapsing a tube, which process eliminates the aforementioned drawbacks and disadvantages, and can prevent moisture from the exterior from mixing in and can reliably and stably perform both the drawing and collapsing steps.

In accordance with this invention, there is provided a process for fabricating an optical fibre by providing a quartz tube with an inner lining of a synthetic glass having a refractive index higher than the quartz, and collapsing the tube while drawing it to form an optical fibre, comprising the steps of forming the synthetic glass lining in the quartz tube so that the ratio of the inner diameter/outer diameter of the quartz tube is 0.85 or less, then sealing one end of the quartz tube, then holding the quartz tube in a furnace, and drawing it from the sealed end while maintaining the interior of the quartz tube under negative pressure.

Embodiments of this invention will now be described by way of examples only and with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of an apparatus used for carrying out a first embodiment of process in accordance with this invention for fabricating an optical fibre;

Figure 2 is a schematic view of an apparatus used for carrying out a second embodiment of process in accordance with this invention; and

Figure 3 is a graph illustrating the fabricating conditions under which the process of the invention is carried out.

Referring to Fig. 1 in a process in accordance with the present invention, a synthetic glass layer 30 is formed as an inner lining to a quartz tube 31 (the synthetic glass having a higher refractive index than the quartz), for example using an MCVD method, so that the ratio of the inner diameter/outer diameter of the quartz tube 31 is 0.85 or less (here, the inner diameter means the inner diameter of the synthetic glass layer 30). Then, one end 42 of the quartz tube 31 is sealed. Subsequently, the quartz tube 31 is held by a support 32 in a wire-drawing furnace 33, and a suction system 50 is connected through a connector 40 to the open end 43 of the other end of the quartz tube 31. Here, the suction system 50 has conduits 34, 37, a suction pump 35 connected to the conduits 34, 37, and a gas-feed flow-rate regulator 36. The suction system 50 further has a differential pressure gauge 38 connected to a point in the conduit 37 between the joint 45 of conduits 34 and 37 and the connector 40, and a setting unit 44 is connected to the pressure gauge 38 for setting the flow-rate of inert gas or the like by controlling the flow-rate regulator 36 in accordance with the measured pressure value.

Thus, after the quartz tube 31 and the suction system 50 are connected, they are evacuated to a predetermined pressure by the pump 35, the gas flow-rate is regulated by the regulator 36 for introducing gas while the internal pressure in the quartz tube 31 is monitored by the pressure gauge 38, and the pressure in the tube 31 is maintained at predetermined negative pressure. The negative pressure is optimum when in the range 0 to −22mm H_2O, for the reason to be described below.

When this state is stabilized, an optical fibre 41 is drawn from the sealed end 42 of the quartz tube 31. Numeral 45 designates a coating unit for coating the optical fibre 41, and numeral 39 designates a capstan used to draw the optical fiber.

The control of the internal pressure in the quartz tube 31 may be performed, for example, by providing an automatic switching

valve before the pump 35, controlling the opening of this valve through a setting unit for operating in accordance with the indicated value of the differential pressure gauge, or using a suction pump for regulating the suction amount by a frequency conversion, but when the internal pressure to be controlled is ultrafine value like a range of 0 to −22m H_2O, it is convenient to allow the suction pump 35 always to such at a predetermined rate, as shown, and to regulate the rate of flow of gas from the exterior using the regulator 36 and setting unit 44. Thus, even if a cause of instability occurs, such as pulsation in the pump 35, ultrafine pressure regulation can still be maintained effectively.

In the embodiment described with reference to Fig. 1, the gas to be introduced via the regulator 36 is an inert gas such as argon or helium, because the invasion of atmospheric air from the exterior, and particularly the invasion of moisture carried in the atmosphere, is prevented by the inert gas. This invention is not limited to the particular embodiment. For example, dry oxygen may be also used. Halogen gas such as chlorine gas, or further halogen has containing no hydrogen such as Freon gas or thionyl chloride, may be introduced instead of the inert gas and if the pressure of the gas in the quartz tube 31 is regulated, it can also prevent moisture from the atmosphere ivading, and can preferably remove the moisture in the quartz tube 31 more efficiently. Of course, if the seal of the quartz tube against the exterior is complete, the inert gas or the halogen gas may not be used.

Fig. 2 shows a second embodiment of the process in accordance with the invention, in which a dehumidifying process is conducted before the process which has been described with reference to Fig. 1. A synthetic glass layer 30 of refractive index higher than a quartz tube 31, is formed as a lining in the quartz tube 31, one end 42 of the quartz tube 31 is sealed, a suction system 50 is then hermetically connected to the open end 43 of the quartz tube 31, and the quartz tube 31 is evacuated by a suction pump 35 whilst heated by a heating furnace 51 to a range, for example, of 100°C to 500°C. The reason why the upper limit of the heating temperature is limited to 500°C is because, if the temperature were higher than 500°C, moisture would react with the quartz so that the moisture would be introduced into the quartz. Since it is not necessary to regulate the pressure in the quartz tube 31 as in case of the previously-described process, a valve 52 is provided between the joint 45 of the suction system 50 with a flow-rate regulator 36 showing in Fig. 1, and the quartz tube 31 is evacuated by closing this valve. Here, numeral 53 designates a valve provided between the joint 45 and the suction pump 35, which is naturally openen whilst suction is being applied by the suction pump 35. When a trap 55 is provided between the valve 53 and the suction pump 35, it can prevent the pump 35 from being corroded by corrosive gas, and can simultaneously prevent preferably reverse gas flow from flowing from the suction pump 35 side, but this trap is not indispensable.

As described above, when the quartz tube 31 is dehumidified completely, the valve 52 is opened, the valve 53 is closed, and inert gas or halogen gas as descried with respect to Fig. 1 is then introduced from the exterior into the quartz tube 31 via the flow-rate regulator 36, and the quartz tube 31 is moved to the drawing furnace 33 in the state that the quartz tube 31 is filled with the gas. A flexible pipe 54 may conveniently be provided as part of the connection of the joint 45 to the open end 43 of the quartz tube 31 so as to facilitate this movement of the quartz tube.

Thus, after the quartz tube 31 is moved to the drawing furnace 33, the valve 53 is opened, and the same operation as described with respect to Fig. 1 is conducted to draw the optical fibre.

The reason why the ratio of the inner diameter/outer diameter of the quartz tube 31 is set ot 0.85 or less and the reason why the internal pressure is controlled optimally to the range 0 to −22mm H_2O will now be described.

When the quartz tube 31 is generally evacuated, a force acts in the collapsing direction on the quartz tube, owing to differential pressure between the interior and the exterior of the quartz tube. The prime cause of the collapse is ordinarily the surface tension of melted glass, but if a differential pressure is produced between the exterior and the interior of the quartz tube as descried above, the quartz tube 31 may be more readily collapsed. However, if this differential pressure is excessively large, since the collapsing step of the quartz tube 31 itself is unstable, the quartz tube 31 might be deformed to non-circular shape. Therefore, the differential pressure should have a restricted range. This value is affected by the influence of the size of the quartz tube 31, and particularly the ratio of the inner diameter/outer diameter and the viscosity of the quartz tube 31. Naturally, the smaller the ratio of the inner diameter/outer diameter, the smaller the size of the hollow portion in the quartz tube. Accordingly, if the contraction rate of the quartz tube 31 in the case of collapsing is smaller, a quartz tube 31 having less deformation can be readily provided. Consequently, even if the differential pressure is low, the collapsing step can be performed, while even if the differential pressure is, on the contrary, excessively high, the quartz tube is not so deformed. More particularly, the range of the differential pressure of the quartz tube can be increased. On the one hand, in the case when the ratio of the inner

diameter/outer diameter is large, since the contraction rate is large, if the differential pressure is excessively low, the quartz tube is hardly collapsed, while if the differential pressure is excessively high, the quartz tube may be readily deformed. In other words, the range of the suitable differential pressure is narrowed. On the other hand, the viscosities of both the quartz tube 31 and the synthetic glass layer 30 affect the range of the differential pressure. As to the quartz 31, the case of an ordinary quartz glass tube, its viscosity depends upon the content of the HO group, and if this content becomes less, the viscosity becomes larger. On the other hand, as to the synthetic layer 30 of the inner layer, if various dopants are added to the SiO_2, its viscosity decreases, and is proportional to the amount of the dopant. In a quartz tube having low viscosity, the tube may be readily collapsed and also deformed. Therefore, if the values of the inner diameter/outer diameter are equal, the differential pressure depends upon the smaller one. On the other hand, if the viscosity increases, the quartz tube may hardly be deformd, and hardly collapsed. Thus, if the values of the inner diameter/outer diameter are the same, the differential pressure depends upon the larger one. The following experiments have been executed so as to determine the ration of the inner diameter/outer diameter as well as the differential pressure range according to the above-mentioned prerequisites.

EXPERIMENT 1

A synthetic glass layer 30 of SiO_2 with 1 mol-% of P_2O_5 added, was formed on the inner surface of a natural quartz tube 31 of content (water content) of OH group of approximately 200 ppm having low viscosity in such a manner that the sectional area ratio was 3.3:1.0, and several samples of different inner diameter/outer diameter ratios were prepared. They were heated to approximately 2100°C in a wire-drawing furnace 33 to provide an optical fibre 41 having a 125 micrometer outer diameter. At this time, the internal pressure of the quartz tube 31 was up to $0mmH_2O$, and evacuated gradually to negative pressure, and sampled at intervals and the shape was measured at every time. The wire-drawing velocity was approximately 80 m/min, and the wire-drawing velocity was approximately 10g. It was found that the results could be expressed as the solid line A–B–C in Fig. 3. Here, the region (11) outside A–B had an uncollapsed portion in the quartz tube 31, and the region (13) outside B–C had a portion including large deformations unavailable for use, and the region (12) inside A–B–C had no uncollapsed portion nor any deformation, being preferable conditions.

EXPERIMENT 2

A synthentic glass layer 30 of pure SiO_2 was formed on the inner surface of a unhydrate quartz tube 31 of content (water content) of OH group of approximately 1 ppm having high viscosity in such a manner that the sectional area ratio was 3.3:1.0, and several samples of different inner diameter/outer diameter ratios were prepared. An optical fibre 41 having 120 micrometers outer diameter was provided in the same manner as in EXPERIMENT 1. At this time, the internal pressure of the quartz tube 31 was up to $0mmH_2O$, and evacuated gradually to negative pressure, sampled at intervals, and the shape was measured every time. It was found that the results could be expressed by the broken line D–E–F in Fig. 3. Here, the region (11) outside D–E had an uncollapsed portion in the quartz tube 31, and the region (13) outside E–F had a portion including large deformations and therefore unavailable for use, and the region (12) inside D–E–F had no uncollapsed portion nor any deformation, being preferable conditions. In Fig. 3, when the ratio of the inner diameter/outer diameter of the quartz tube 31 is 0.85 or less and the internal pressure is in the range 0 to $-22mmH_2O$, stable drawing and collapsing can be performed simultaneously. If the ratio of the inner diameter/outer diameter of the quartz tube 31 is 0.1 or less, the hollow portion of the tube 31 is very small, so that the effect of this invention is very small in the range of 0.1 or less.

According to the present invention as described above, in the case of simultaneously drawing and collapsing, the process can prevent moisture from invading from the exterior and provide an optical fibre having no deformation and therefore high quality.

CLAIMS

1. A process for fabricating an optical fibre by providing a quartz tube with an inner lining of a synthetic glass having a refractive index higher than the quartz, and collapsing the tube while drawing it to form an optical fibre, comprising the steps of forming the synthetic glass lining in the quartz tube so that the ratio of the inner diameter/outer diameter of the quartz tube is 0.85 or less, then sealing one end of the quartz tube, then holding the quartz tube in a furnace, and drawing it from the sealed end while maintaining the interior of the quartz tube under negative pressure.

2. A process according to Claim 1, wherein the optical fibre is drawn from the sealed end of the tube while maintaining the internal pressure of said quartz tube in the range 0 to $-22mmH_2O$.

3. A process according to Claim 1, wherein the optical fibre is drawn from the sealed end of the tube while maintaining an inert gas atmosphere in said quartz tube and maintaining the internal pressure of said quartz tube in the range 0 to $-22mmH_2O$.

4. A process according to Claim 1, wherein the optical fibre is drawn from the sealed end of the tube while maintaining a halogen gas or halogenide containing no hydrogen in said quartz tube and maintaining the internal pressure of said quartz tube in the range 0 to $-22mmH_2O$.

5. A process according to any one of Claims 1 to 4, wherein gas in said quartz tube is withdrawn by a suction pump from the open end of said quartz tube to control the internal pressure therein.

6. A process according to any one of Claims 1 to 5, wherein a flow-rate regulator is provided in a conduit for coupling between the open end of said quartz tube and a suction pump to thereby regulate the rate of introduction of the gas to control the internal pressure in said quartz tube.

7. A process as claimed in Claim 1 and substantially as herein described with reference to Fig. 1 or 2 of the accompanying drawings.

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